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INS A1>

Title: Continuous casting and rolling plant, in particular thin-slab continuous casting and rolling plant

SUB A2>

~~Description~~

The invention relates to a method of operating a continuous casting and rolling plant, in particular a thin-slab continuous casting and rolling plant, with a computing unit, A ~~a~~ plurality of slabs which belong to different production orders are ~~being~~ produced within sequences on the continuous casting and rolling plant. The invention likewise relates to a continuous casting and rolling plant, in particular a thin-slab continuous casting and rolling plant, in which case a plurality of slabs which belong to different production orders can be produced within sequences on the continuous casting and rolling plant.

Insert A Methods ~~Such methods~~ of operating a continuous casting and rolling plant and also such continuous casting and rolling plants are generally known and are in operation in many cases.

It is likewise known that continuous casting and rolling plants are subjected to technical restrictions which result, for example, from the service life of parts of the plant. For example, the splitting-up of the operation of the continuous casting and rolling plant into individual sequences is a consequence of such technical restrictions.

Different production orders are processed with continuous casting and rolling plants, and also with thin-slab continuous casting and rolling plants. These production orders result in order-related restrictions, for example with regard to the desired steel grade or the desired thickness and width of the respective end product.

It is known that the technical and the order-related restrictions lead to a situation in which it is very difficult to operate the continuous casting and rolling plant in an optimum manner with different production orders in a so-called production mix. For example, with regard to the utilization rate of the continuous casting and rolling plant, the technical restrictions and the order-related restrictions are virtually opposed to one another, so that it has scarcely been possible hitherto to achieve optimum operation in this respect with different orders of the continuous casting and rolling plant.

INSA4 >

The object of the invention is to provide a method of operating a continuous casting and rolling plant, in particular a thin-slab continuous casting and rolling plant, which ~~method~~ permits optimized operation.

In a method of the type mentioned at the beginning, this object is achieved according to the invention in that the order of the slabs belonging to the production orders within the sequences is determined with the computing unit by a genetic algorithm. Further, ~~and that~~ the continuous casting and rolling plant is controlled by the computing unit in accordance with the order determined. In a continuous casting and rolling plant of the type mentioned at the beginning, the object is achieved according to the invention by the use of a genetic algorithm for determining the order of the slabs belonging to the production orders within the sequences.

It has been found that largely optimized operation of the continuous casting and rolling plant can be achieved by means of the genetic algorithm. The genetic algorithm is able to take into account the technical and the order-related restrictions in an optimized manner. With the aid of the genetic algorithm, an order of the slabs within the sequences can be produced. ~~produced,~~ The ~~which~~ order of the slabs, despite the ~~said~~ restrictions, permits optimized operation of the continuous casting and rolling plant, for example with regard to the utilization rate of the latter.

In an advantageous configuration of the invention, the order of the slabs belonging to the production orders within the sequences is determined with the computing unit by an event-oriented evaluation, and the continuous casting and rolling plant is controlled by the computing unit in accordance with the order determined.

It has been found that the event-oriented evaluation interacts with the genetic algorithm in an especially effective manner. Operation of the continuous casting and rolling plant in a manner optimized to an especially large extent is obtained with the event-oriented evaluation and the genetic algorithm.

The method according to the invention can be used in an especially effective manner in thin-slab continuous casting and rolling plants. On account of the technical restrictions present there, which are even more extensive, the genetic algorithm in particular is especially suitable for ensuring optimized operation of the plant.

INSA5

Further features, possible applications and advantages of the invention follow from the description below of exemplary embodiments of the invention, which are shown in the figures of the drawing. In this case, all the features described or shown form the subject matter of the invention on their own or in combination, irrespective of their compilation in the patent claims or when

referring back to them and irrespective of their wording and representation in the description and the drawing, respectively.

Figure 1 shows a schematic block diagram of an exemplary embodiment of a thin-slab continuous casting and rolling plant according to the invention,

figure 2 shows a schematic representation of exemplary sequences of the thin-slab continuous casting and rolling plant of figure 1,

figure 3 shows a schematic block diagram of an exemplary embodiment of a method according to the invention for operating the thin-slab continuous casting and rolling plant of figure 1, and

figure 4 shows a schematic representation of product-dependent sequences of the thin-slab continuous casting and rolling plant of figure 1 which have been prepared according to the method in figure 3.

INS A6 A thin-slab continuous casting and rolling plant 1, which is intended for the manufacture of sheets for example, is shown in figure 1. The thin-slab continuous casting and rolling plant 1 includes ~~consists of~~ three casting strands 2, 3, 4, which are united in a following tunnel furnace (CFT) 5. Following the latter is a hot strip mill (HSM) 6 for the further processing.

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In the casting strand 2, crude steel is fed to a ladle furnace 7, which serves to alloy the steel

as a function of the desired melt sizes. Arranged downstream of the ladle furnace 7 is a vacuum degasser (VD) 8, with which the steel is degassed as a function of the desired steel grade. This is followed by a continuous caster (CC) 9, with which the steel is cast into slabs. After the casting process, the slab is cut to its length specified in the order in order to subsequently enter the tunnel furnace.

It is possible for there to be no ladle furnace 7 and no vacuum degasser 8 in the casting strand 2, so that the crude steel is introduced directly into the continuous caster 9.

An electric arc furnace (EAF) 10 is provided in each of the two casting strands 3, 4, the two electric arc furnaces 10 being fed with scrap. The scrap is melted in the electric arc furnaces 10. Arranged in each case downstream of the electric arc furnaces 10 are a ladle furnace 11 and a vacuum degasser 12, which have the functions already described in connection with the casting strand 2. These are followed in each case by a continuous caster 13.

Slabs are produced by the casting of the steel by means of the continuous casters 9, 13, and these slabs pass through the tunnel furnace 5. The slabs pass directly from the respective distributors into the tunnel furnace. Inside the tunnel furnace 5, these slabs may

be at least briefly cushioned, and pre-drawing of individual slabs is also possible.

Provided for the shaping of the slabs at each continuous caster are a distributor and molds and segments, through which the melts are poured and become slabs. The molds and the segments can be adjusted at a distance from one another, so that the width and the thickness of the slab are adjustable. Since the plant is a thin-slab continuous casting and rolling plant, the slabs upstream of the hot strip mill 6 have a mold-dependent thickness in the region of about 50 mm.

Unlike continuous casting and rolling methods in general, the slabs produced in the case of the thin-slab continuous casting and rolling plant of figure 1 are not stored. Instead, the slabs are immediately fed to the hot strip mill 6. As identified in figure 1 with the reference numeral 15, the slabs are fed one after the other to the hot strip mill 6 for processing, that is to say, two slabs are no longer fed simultaneously or in parallel, as is the case in the tunnel furnace 5.

In the hot strip mill 6, the slabs are repeatedly passed through roll pairs and are thereby reduced in their thickness. The hot strip is obtained, which approximately has a thicknesses of between 1 mm and 12 mm. The hot strip mill 6 is often followed by a cold strip mill, with which the slabs are subjected to a further reduction in thickness. The end product obtained

at the outlet of the cold strip mill is the cold strip, which is, for example, a sheet having a thickness of 0.8 mm to 1 mm.

Inter alia, the parts of the thin-slab continuous casting and rolling plant 1 which have been described each have a certain service life. Thus, for example, the distributors of the continuous casters 9, 13, after a certain quantity of liquid steel has passed through, must be cleaned, heated and, if need be, also partly renewed. This correspondingly applies to the molds and the segments. In the hot strip mill 6 and the cold strip mill, the rolls have to be renewed after a certain rolled length of slabs have passed through. These operations are designated as setting-up or set-up.

The continuous casters 9, 13 may be set up independently of one another at different times. The hot strip mill is set up without interrupting the casting process. The setting-up at the continuous casters 9, 13 interrupts the continuous casting of slabs. The interval between two set-ups is designated as sequence.

If the thin-slab continuous casting and rolling plant 1 is considered from the point of view of the tunnel furnace 5, a pattern is obtained which is explained below with reference to figure 2. In this case, figure 2 is

a diagram plotted against time t, this diagram indicating the time sequence of operations in the tunnel furnace 5.

As has been described, two strands 16, 17 pass with successive slabs through the tunnel furnace 5. Each of these strands consists of successive sequences 18 and set-ups 19. Each of the sequences 18 is composed of individual melts 20, certain slabs 21 in each case being assigned to the individual melts 20.

The sequences 18 and set-ups 19, as described, result from the service life of the parts of the thin-slab continuous casting and rolling plant 1. The melts 20, which are also designated as heats, involve different steels, for example different steel grades, which are produced via the various casting strands 2, 3, 4 and are fed to the tunnel furnace 5. The slabs 21 each have, for example, the steel grade of that melt 20 from which they have been produced. In this case, a plurality of slabs 21 can be produced from one of the melts 20, as shown in figure 2.

By way of example, figure 2 shows how, in the case of the strand 17, the first sequence 18 is composed of a total of four melts 20, which in turn are provided for producing a total of 87 slabs.

Within one of the sequences 18, that is, for example, within the aforesaid first sequence 18, only melts 20 whose steel grades are compatible with one another can be processed. The melts 20 must belong to a so-called steel-grade family. Melts 20 having other steel grades cannot be used until after a set-up 19. This constitutes a technical restriction for the thin-slab continuous casting and rolling plant 1.

As has been explained, the sequences 18 depend on the service life of the parts of the thin-slab continuous casting and rolling plant 1. This constitutes a further technical restriction for the thin-slab continuous casting and rolling plant 1.

As has likewise been described, the width and the thickness of the slabs may be influenced by means of the molds and the segments. However, this is not possible in any desired manner. Thus, for example, the width of the slabs may only be changed from a larger width to a smaller width within one and the same sequence. In this way, there are further technical restrictions for the thin-slab continuous casting and rolling plant 1 which have to be taken into account during operation of the same.

With the thin-slab continuous casting and rolling plant 1 described which has the technical restrictions likewise described,

production orders are executed which have order-related restrictions.

These order-related restrictions involve, for example, the steel grade and the quality of the steel which is desired in a production order and is to be used. A further order-related restriction of a production order consists in the desired thickness and width of the end product to be manufactured, that is, for example, of the desired sheet. Finally, the quantity or the tonnage of the respective production order also constitutes an order-related restriction.

A method of operating the thin-slab continuous casting and rolling plant 1 is shown in figure 3, with which method the aforesaid technical and order-related restrictions can be taken into account.

The method in figure 3 constitutes a combination of a genetic algorithm and an event-oriented evaluation. In the method, first of all an initial or starting solution is defined in order to then determine an iteration process for the operation of the thin-slab continuous casting and rolling plant 1. If a discontinuation criterion has been fulfilled, the method is terminated. The best solution determined then constitutes a solution with which the thin-slab continuous casting and rolling plant 1 can be operated in an optimized manner with regard to the

technical and order-related restrictions.

Shown in figure 3 is a block 22 which is provided for determining and defining the solution space. There, all the data required for carrying out the method are input into a computing unit by a user. This operation is also designated as coding.

Inter alia, these are the data which belong to the individual production orders, that is, for example, delivery dates, quantities to be delivered, and the like. In particular, the data are those which characterize the order-related restrictions, that is, for example, the steel grades of the respective production order, the quality of the steel, the desired width and thickness of the end product, and the like.

From these data, the computing unit, in block 22, determines a first solution with which the existing technical and order-related restrictions in the thin-slab continuous casting and rolling plant 1 could be met per se. In this case, the first solution constitutes a proposal as to how the individual slabs belonging to the production orders are to be produced in succession on the thin-slab continuous casting and rolling plant 1. The first solution, which is also designated as starting solution, is a solution

in which the thin-slab continuous casting and rolling plant 1 would more likely be operated in an unsatisfactory manner.

The first solution determined in block 22 is evaluated by the computing unit in a block 23. To this end, an event-oriented evaluation is carried out on the basis of the existing starting solution. In the process, the operation of the thin-slab continuous casting and rolling plant 1 is simulated by the computing unit using the values of the starting solution.

The technical restrictions of the thin-slab continuous casting and rolling plant 1 are taken into account during this simulation. These are, inter alia, the operating parameters of the thin-slab continuous casting and rolling plant 1, that is, for example, the number of casting strands 2, 3, 4, the number and type of continuous casters 9, 13, the number of slab strands passed through in the tunnel furnace 5, the number and type of rolls of the hot rolling mill 6, and the like. Likewise involved in this case are those data which characterize the technical restrictions, that is, for example, the possible widths and thicknesses of the slabs or the incremental ranges or the like.

Therefore all the events which are necessary for planning and which would take place during operation of the thin-slab continuous casting and rolling plant 1 are simulated by the computing unit. It is thus possible for the computing unit to determine certain simulation results.

These simulation results may involve, inter alia, the processing time which is necessary in order to fulfill a certain production order. This may involve the periods which arise when using the first solution for the individual sequences 18. It may involve that utilization rate of the thin-slab continuous casting and rolling plant 1 which is obtained with this starting solution. Such simulation results and other simulation results may be determined by the computing unit and made available as initial information of block 23.

In a block 24, a selection is made by the computing unit on the basis of the simulation result made available. The criterion for this selection is the quality of the simulation result. This quality is calculated by the computing unit from the simulation result, specifically with regard to meeting the technical and order-related restrictions as far as possible in an optimized manner.

The following criteria may be included in this calculation of the quality of a simulation result. The thin-slab continuous casting and rolling plant 1 is to be utilized as effectively as possible. The individual parts of the thin-slab continuous casting and rolling plant 1 are likewise to be utilized as effectively and uniformly as possible. The existing casting strands 2, 3, 4 and the continuous casters 9, 13 are to be operated as synchronously as possible. The longest possible service life of the

parts of the thin-slab continuous casting and rolling plant 1 is to be achieved. There is to be as little scrap as possible during the entire manufacturing process. The delivery dates stipulated in the individual production orders are to be adhered to. The requirements imposed on the end product to be manufactured, that is, for example, the width, the quality and the like, are to be adhered to.

Such criteria and other criteria can be taken into account by the computing unit when determining, in block 24, the quality of the simulation result made available by block 23.

Depending on the quality determined by the computing unit, a decision is made as to whether the method is to be continued or terminated. If the quality exceeds an intended discontinuation criterion, this means that the desired quality is reached and the method is terminated. However, if this is not the case, the method is continued with block 25. This is normally always the case during the first pass on the basis of the starting solution determined by block 22.

In block 25, a genetic algorithm is applied to the actual generation of solutions. In the process, the individual values of the solution are subjected to a selection and/or a

recombination and/or a mutation. These measures are also designated as genetic operators.

The aforesaid selection refers to a reproduction in which certain values of the solution are increased as a function of their quality. During the recombination, values of the solution are interchanged and, if need be, are additionally combined with one another. During the mutation of the solution, certain values of the same are changed individually and, if need be, new values are additionally added.

Genetic algorithms and their use are known from the following publications:

DeJong, K. (1985): Genetic Algorithms: A 10 Year Perspective, Proceedings of an International Conference on Genetic Algorithms and their Applications: pages 169-177, Hillsdale, N. J.;

Goldberg, D. E. (1989): Genetic Algorithms in Search, Optimization, Machine Learning, Addison-Wesley Publishing Company, Inc., Reading, Massachusetts;

Goldberg, D. E. (1989): Zen and the Art of Genetic Algorithms, Proceedings of the Third International Conference on Genetic Algorithms, pages 80-85, Morgan Kaufmann Pub., Palo Alto;

Schulte, J. W., Becker, B. D. (1993): Optimierung in der Werkstattsteuerung: Simulation und Genetische Algorithmen [Optimization in workshop control: simulation and genetic algorithms], Simulationstechnik 8th Symposium in Berlin, ASIM Berlin, September 1993, pages 599-602.

After the values of the solution have been subjected to the genetic algorithm, the new solution produced is fed to block 23 again. There, as has already been explained, the solution is evaluated. After that, the determined simulation results are fed to block 24, which, as has likewise been described, determines the quality of the simulation results and, as a function thereof, continues or discontinues the method.

In this way, the method is continued until the desired quality is achieved and thus a solution achieving this quality is found. This solution is an optimized solution which is taken as a basis for the operation of the thin-slab continuous casting and rolling plant 1.

A product-dependent sequence 26 of the thin-slab continuous casting and rolling plant 1 of figure 1 is shown by way of example in figure 4, which product-dependent sequence has been prepared according to the method in figure 3. As has already been explained in connection with figure 2, the sequence 26, 27 in each case follow a set-up. There are a plurality of melts 28 in the sequences 26, 27, these melts being provided for the production of a multiplicity of slabs 29.

Unlike the representation of figure 2, the slabs 29 are no longer just "any" slabs but are certain slabs which are assigned to certain production orders 30, 31. This follows from figure 4 by virtue of the fact that the individual slabs 29 are provided with identifying marks whose second digit identifies the respective production order 30, 31 and whose first digit indicates the number of the slab 29 in the production order 30, 31. The "slab 4,1" therefore means the fourth slab 29 of the first production order 30.

It is essential in figure 4 that the slabs 29 of the individual production orders 30, 31 are no longer processed one after the other within the sequences 26, 27. This change in the order of processing is determined and controlled by the method in figure 3. With the change, the technical and the order-related restrictions of the thin-slab continuous casting and rolling plant 1 are taken into account by the method in figure 3. The computing unit mentioned in connection with figure 3 then controls the thin-slab continuous casting and rolling plant 1 in such a way that the progress of the sequences 26, 27 which is shown in figure 4 is obtained.

With the aid of the method described, it is thus possible to distribute the slabs 29 of the individual production orders 30, 31 to the sequences 26, 27 in such a way that the thin-slab continuous casting and rolling plant 1 is operated in an optimized manner. This

distribution is determined by the computing unit according to the method in figure 3. Accordingly, the thin-slab continuous casting and rolling plant 1 is controlled by the computing unit in such a way that the order determined of the individual slabs 29 belonging to the production orders 30, 31 within the sequences 26, 27 is actually implemented.

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